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ORIGINAL PAPER

Combining the categorical and the dimensional perspective in a diagnostic map of psychotic disorders

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Abstract We introduce a diagnostic map that was calculated by robust non-metric multidimensional scaling based on AMDP symptom profiles of patients with schizophrenic and affective disorders to demonstrate a possibility to combine the categorical and the dimensional perspective at the same time. In the diagnostic map, a manic, a depressive, and a non-affective cluster clearly emerged. At the same time, the mania dimension ($r = 0.82$), the depression dimension ($r = 0.68$), and the apathy dimension ($r = 0.74$) showed high multiple regression values in the map. We found substantial overlaps of the diagnostic groups with regard to the affective spectrum but irrespective of the ICD-10 classification. Within this sample, we found the association and quality of mood symptoms to be a structuring principle in a diagnostic map. We demonstrate that this approach represents a promising way of combining the categorical and the dimensional perspective. As a practical implementation of these findings, a multidimensional diagnostic map could serve as an automated diagnostic tool based on psychopathological symptom profiles.

Keywords Mental disorders · Classification · Diagnosis

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Introduction

In his paper on the philosophical roots of schizophrenias, Michael Musalek [32, p. S16] notes: "…nature obviously is completely unimpressed by human made principles of rules and systems. Nature itself does not know these forms and categories invented by human beings." This statement illustrates, with a good deal of humor, the ongoing debate in psychiatric classification in general and in the field of psychotic disorders in particular: The question of whether to look at psychiatric disorders from a categorical or a dimensional point of view, e.g. [9, 13, 40]. In the field of psychotic disorders, this discussion emerged especially prominently in the forum on the weight of the disadvantages of the Kraepelinian dichotomy in the June 2007 issue of World Psychiatry and in the July 2007 issue of the Schizophrenia Bulletin presenting proceedings of the "Deconstructing Psychosis" conference of the American Psychiatric Association (APA), the World Health Organization (WHO), and the US National Institutes of Health (NIH). While biological and genetic data in particular do not seem to support a dichotomous separation of psychotic (i.e. F2) and bipolar/mood (i.e. F3) disorders [10, 27], other studies found support for a separation of schizoaffective disorders from schizophrenia with regard to clinical picture and outcome [20, 28]. A dimensional approach seems to be superior in terms of predictive validity [2], but of course the categorical status of current classification systems, the usefulness and simplicity of categorical decisions [40], and a tendency of human beings to think in categories [13] should not be neglected either. The conclusion is obvious: A combination of the categorical and the dimensional perspective would seem to be the most promising approach. This can also be gleaned from the canon of current research literature with regard to psychiatric classification in general, e.g. [22, 23, 35], and the field of psychotic disorders in particular, e.g. [2, 11, 39]. Many fruitful methodological approaches have been applied and discussed in this regard in order to identify either categories or dimensions, such as cluster analysis, e.g. [21, 25], factor analysis, e.g. [11, 13], latent class analysis [1, 31], or grade-of-membership models [19, 26]. The method [14] that is presented in this study does not attempt a priori to identify clusters, categories or dimensions, but rather depicts the relations between objects in a Euclidean space in a structurally neutral way. In such a space, psychiatric patients can be described based solely on their inter-relations in terms of psychopathology, and the structure can then be interpreted from both, a categorical and a dimensional perspective at the same time. Therefore, such a descriptive Euclidean space presents a method particularly suited to depict the “fundamental equivalence” [18, p. 656] of categorical and dimensional approaches. The task of constructing such a space can be accomplished by the statistical instrument of non-metric multidimensional scaling (NMDS), e.g. [8], because it is based on an iterative algorithm positioning the items (i.e. patients) in an optimal configuration without introducing new explanatory dimensions by principle component analysis. In the case of a two-dimensional multidimensional space, this instrument not only allows to statistically model dimensional and categorical diagnostic aspects within an Euclidean space but also allows these aspects to be visualized (by a priori cluster analysis and property fitting of external scales) in a comprehensible manner.

As a database, we used the diagnostically independent psychopathology rating scale AMDP [3], which is often used in the exploration of categorical and dimensional aspects of psychotic disorders [11, 20, 36, 37]. We will demonstrate that the combination of the structurally neutral statistical approach of NMDS with a set of diagnostically independent symptom data offers a new perspective for modeling qualitative diagnostic structural aspects and builds the basis for a potential clinical application of the diagnostic map with regard to diagnostic positioning.

Methods

Sample and clinical data

The sample consisted of cases from the psychiatric hospital of the Ludwig-Maximilians University in Munich who were admitted and discharged between January 2002 and December 2003 ($N = 2{,}485$). The psychiatric hospital of the Ludwig-Maximilians University is not only a research hospital but also serves as a primary referral center for patients from the city of Munich and other parts of Bavaria. Thus, a priori selection bias does not apply, and the sample can be seen as representative of a general psychiatric inpatient population. Included for further analysis were the AMDP symptom [3] and ICD-10 [41] diagnostic data that are routinely assessed at admission and discharge based on informed consent of the patients. The AMDP is a psychopathological symptom rating scale (0 = not present, 1 = mild, 2 = moderate, 3 = severe) containing 100 psychopathological and 40 somatic symptoms comprising affective, behavioral, cognitive, psychotic, sensory, and social dimensions of psychopathology. The AMDP system has also been translated into many other languages [16] and has been used in various international studies, e.g. [11, 12, 20, 36, 37]. It is the most widely used and the best known psychiatric documentation system in the German-speaking area [29]. Many empirical studies show that it can be considered a well-established test, for which reliability and validity is reported to be good to very good [5].

Selected diagnoses and cases

Ten diagnoses from the field for which the AMDP was primarily defined (i.e. the organic, schizophrenic, and affective psychotic disorders) were included: F20.0 (paranoid schizophrenia), F20.1 (hebephrenic schizophrenia), F20.2 (catatonic schizophrenia), F20.5 (residual schizophrenia), F25.0 (schizoaffective disorder, manic type), F25.1 (schizoaffective disorder, depressive type), F25.2 (schizoaffective disorder, mixed type), F31.2 (bipolar affective disorder, current episode manic with psychotic symptoms), F31.6 (bipolar affective disorder, current episode mixed), and F32.3 (severe depressive episode with psychotic symptoms). Other diagnostic categories (e.g. F30.2, F31.5, F33.3) were not included since these categories only differ from the ones chosen for this study in terms of course, which is not reflected in the AMDP data. Of those categories differing only in course, those categories exhibiting the higher clinical prevalence were chosen. For all of the cases that fell within one of the selected categories ($N = 625$), inter-correlations of the corresponding AMDP symptom profiles were calculated and summed up for every case within every diagnostic category. This led to a rank order of prototypicality. The 10 most prototypical cases ($N = 100$, as statistically defined be the highest summed up symptom profile inter-correlations) were included for further analysis.

Statistical analyses

Based on the similarity of the AMDP symptom profiles, a multidimensional solution was calculated. As similarity coefficient, we chose the Spearman correlation. A multidimensional solution that is calculated based on a correlation coefficient emphasizes the visualization of qualitative symptomatological relations between patients, while one calculated based on a difference measure would rather focus on the severity of symptoms. Both the Pearson (because of the subtraction of the means in the enumerator) and the Spearman correlation coefficient (because of the consideration of the rank differences) reflect more the course of a profile than the level. Therefore, they are better suited to express qualitative differences than difference measures. Due to the characteristics of the AMDP values (most symptoms are not present in a given patient, and the range of 0–3 of the scale is rather small), the large number of ties in the Spearman coefficient rendered it specifically suitable for this analysis. Interestingly, given these conditions, the ties result in a stronger emphasis on the observation of whether or not a symptom is present, rather than on the observation of whether a symptom is mildly or moderately present. The proximity measure was then analyzed by a robust non-metric multidimensional scaling (NMDS) algorithm [24]. An NMDS interprets the proximities between objects as ordinal relations and transforms them into an n-dimensional solution by visualizing them as distances between the objects in such a way that the correspondence between the proximity relations and the ordinal relations of the distances in the n-dimensional solution is maximized. The remaining deviations are numerically expressed as the stress value, which is therefore the indicator for the badness of fit. In such a multidimensional solution, similar objects (i.e. exhibiting similar symptom profiles) are positioned close together and dissimilar objects are positioned far apart from each other. Clusters can be a posteriori identified by a hierarchical cluster analysis of the distance matrix derived from NMDS, and external scales can be fitted into the multidimensional solution by property fitting, a procedure based on multiple regressions [8]. The severity scores on the AMDP syndromes (building the scales for the property fitting procedure) were calculated by summing up the symptom scores within the corresponding syndromes [33].

Results

To determine the dimensionality of the NMDS solution, a scree test [8] was conducted. Since three-dimensional solutions showed no substantial reduction in the stress value, a two-dimensional solution (or map in this case) was chosen. Figure 1 shows the map that was calculated based on the correlations of the symptom profiles. Each dot in the cluster represents the symptom profile of an individual case. The closer two dots are positioned to each other, the more similar were their corresponding symptom profiles, i.e. the higher was the correlation between the symptom profiles. The stress value of the map is 0.18, which is an acceptable value according to the literature [8], given the number of objects and dimensions. The dots are labeled with the ICD-10 F codes and a case-ID. The depicted clusters were plotted according to a hierarchical cluster analysis (average linkage model) based on the distances in the map without the outliers 20.2_1143 and 20.2_1146. The appropriate number of clusters was determined according to the elbow criterion of the biggest heterogeneity increment, e.g. [4]. The multiple regression values of the AMDP syndromes (depicted as vectors in the map) amount to: apathy (AP) $r = 0.74$, depression (DE) $r = 0.68$, and mania (MA) $r = 0.82$. Only those syndromes with a regression value > 0.6 are depicted, although multiple regressions were also calculated for the other syndromes (hostility $r = 0.45$, paranoid-hallucinatory $r = 0.35$, neurological $r = 0.28$, psychoorganic $r = 0.27$, autonomic $r = 0.16$, obsessive–compulsive $r = 0.15$). This map does not include those cases ($N = 19$) that were further away than the mean distance + 1 SD from the centers of gravity of the diagnostic clusters (as depicted in Fig. 2) in a previously calculated map.

In Fig. 2, the same map is depicted as in Fig. 1. The plotted clusters correspond to the ICD-10 diagnostic entities. It becomes evident that the cases of some clusters exhibit a smaller scattering across the map (F25.1: schizodepressive disorder, F32.3: severe depressive episode with psychotic features, F20.0: paranoid schizophrenia, F20.1: hebephrenic schizophrenia, F25.0: schizomanic disorder, F31.2 bipolar mania with psychotic features, and F31.6: bipolar disorder, mixed episode) than others (F20.2: catatonic schizophrenia, F20.5: residual schizophrenia, and F25.2: schizoaffective disorder, mixed type). It is also apparent that some clusters can be delineated from each other quite well (e.g. the psychotic clusters with manic connotations (F25.0 and F31.2), from those with depressive connotations (F25.1 and F32.3), and from those without an affective connotation (F20.0 and F20.1)), while others overlap with other clusters to a great extent (mainly F20.5 and F25.2). Also, while the above-mentioned psychotic clusters with and without affective connotations can be clearly delineated from each other, they cannot be adequately separated within the same affective or non-affective spectrum (F25.1 and F32.3, F20.0 and F20.1, F25.0 and F31.2).

Discussion

Figure 1 depicts the positions of prototypical psychotic cases in relation to each other based on the similarity of their symptom profiles. The clusters plotted according to the cluster analysis help to identify the emerging three

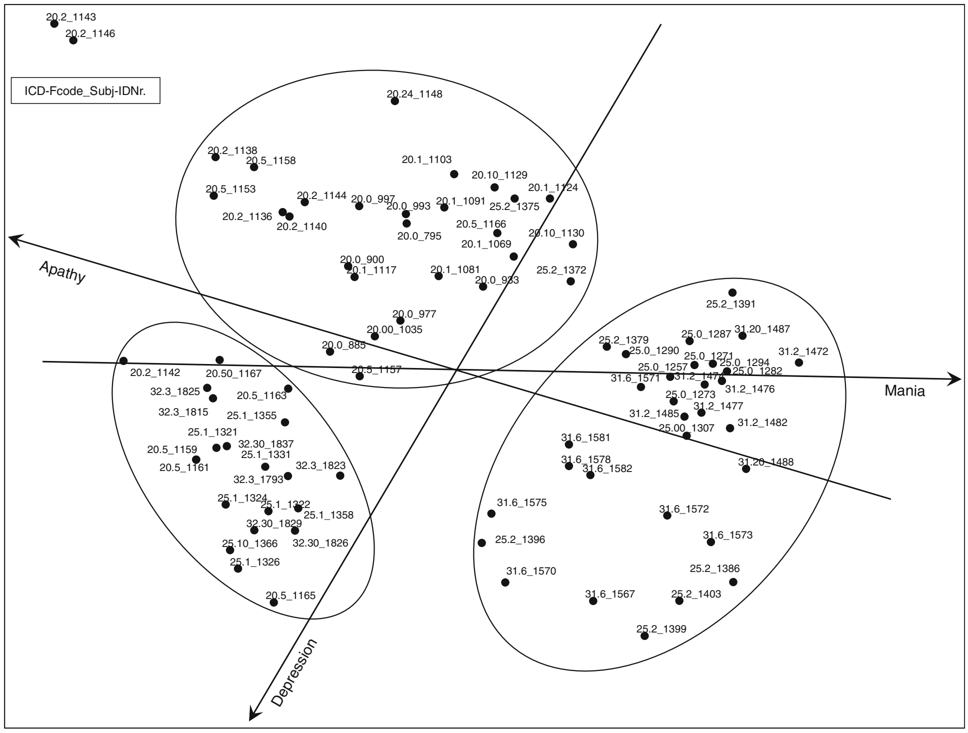

Fig. 1 NMDS map of the prototypical cases across ten diagnostic entities. The stress value is 0.18. The *arrows* depict the vectors and the corresponding regression values of the AMDP syndromes: apathy ($r = 0.74$), depression ($r = 0.68$), and mania ($r = 0.82$). Only those vectors with a regression value >0.6 are depicted. The clusters are plotted according to a hierarchical cluster analysis based on the distances in the map

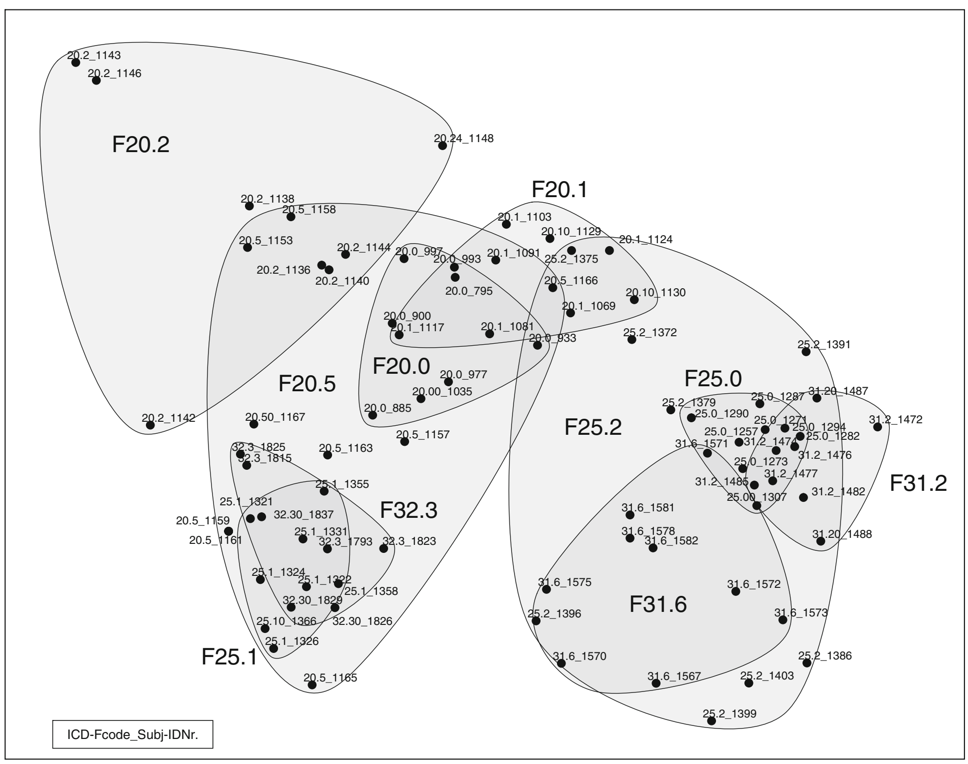

Fig. 2 The same map as in Fig. 1 is presented but including the convex hulls plotted according to the ICD-10 F-categories (independently of the calculation of the map)

clusters. Taking into account the ICD-F codes, the lower cluster on the left can be characterized as psychotic cases with predominantly depressive affective characteristics, the lower cluster on the right as a cluster with psychotic cases with predominantly manic characteristics, and the upper cluster as a cluster including psychotic cases without predominating affective characteristics. Within the cluster on the right, there is an additional separation into an upper and denser region of manic cases and a less dense lower region including mixed cases. Keeping in mind the notion that zones of rarity in multidimensional spaces suggest that patients can be assigned to relatively homogeneous groups [6], this structure indicates that the mood characteristics provide a basis for a categorical view on psychotic cases. These findings are in accordance with a recently published study that identified mood symptoms as the best discriminators of subgroups of psychosis [7]. Although Boks et al. also found a predominantly manic group, a predominantly depressed group and two groups with only a limited number of mood symptoms, they found one additional cluster of patients with a non-psychotic illness and one including patients with almost exclusively depressive symptoms. However, this might be connected with the fact that they relied on another database (the comprehensive assessment of psychiatric history; CASH) and a selection of patients that also included other diagnostic categories such as brief psychosis, NOS, and undifferentiated diagnoses, which were excluded in this study. The rather clear affective clustering in the map is in accordance with the dimensional point of view, which is supported by the observation that especially the affective AMDP syndromes (manic, depressive and apathy) show high regression values in the map (depicted as vectors in the map). The other AMDP syndromes showed only minor multiple regression values ($r \leq 0.45$). These results are congruent with the hypothesis that a psychotic dimension such as the paranoid-hallucinatory syndrome does not discriminate well in a sample that consists of only psychotic patients. The same affective dimensions as in this study were also found by Cuesta and Peralta [11] in their hierarchical dimensional approach to psychosis. On the highest hierarchical level, they also found a manic-depressive and a non-affective dimension. The non-affective dimension subsumes the psychomotor poverty dimension, which includes most of the symptoms of the AMDP apathy syndrome. Looking at the orientations of the dimensions in the map, however, one difference to the study by Cuesta and Peralta catches the eye: While the apathy and the mania dimension in the map exhibit only a small angle and almost opposite orientations (which speaks for a high negative interdependence), Cuesta and Peralta did not find a substantial negative factor intercorrelation between mania and the psychomotor poverty factor in their study (although they did use an oblique factor rotation that assumes the existence of interdependences). Taken together, the categorical and dimensional findings reported earlier illustrate well the possibilities offered by the diagnostic map to combine the categorical and dimensional perspective within the same view at one glance. Additionally, the clinically meaningful position of the mixed part of the cluster on the right, between the depressive cluster on the left and the upper manic part of the right cluster, indicates that it is also possible to interpret the positions of the clusters in relation to each other and even to interpret the orientation of the cases within a cluster.

The categorical aspects with regard to the diagnostic entities are more clearly highlighted in Fig. 2, in which the clusters corresponding to the ICD-10 categories are plotted. In this map, it becomes more clearly evident that, while psychotic cases exhibiting differing affective characteristics can be quite clearly separated from each other (F25.0 from F25.1), no clear categorical separation of the schizoaffective cases (F25.0 and F25.1) can be found from the affective cases with psychotic symptoms (F32.3 and F31.2). This is in line with studies presenting findings that schizoaffective cases could not be separated from affective cases [20, 34]. However, these studies based their findings on outcome data.

The rather large extension of the residual schizophrenia cluster (F20.5) illustrates that this cluster is diagnostically mainly defined by the absence of typically schizophrenic symptoms (although they had to be present at some point) and an existence of predominantly negative symptoms, which can be interpreted to be similar (at least in part) to depressive symptoms. Most of the cases subsumed in this cluster could also have been included in other diagnostic clusters. This observation seems to confirm statements made in the literature that "the residual type of schizophrenia is essentially a place filler…" [30, p. 158]. The somewhat distantly positioned large cluster of cases diagnosed with catatonic schizophrenia (F20.2) suggests that the corresponding symptom profiles can be differentiated from the other psychotic disorders quite clearly but are not very similar to each other. However, there is an overlap, where some cases with residual schizophrenia and cases with catatonic schizophrenia (20.5_1153, 20.5_1158, 20.2_1136, 20.2_1140, and 20.2_1144) are located quite closely together, suggesting a similar symptom profile. This overlap might also illustrate the difficulty of delineating certain symptoms from each other or a variability in symptom recognition such as affective flattening depending on the diagnosis that the clinician has in mind [38]. Interestingly, all six cases show a score of at least "mild" on this symptom. In summary, the depiction of the diagnostic clusters in the continuous space, calculated based on the symptom profiles, allows a critical glance at the diagnostic entities. The interpretation of the orientations and positions of the clusters as well as individual cases helps to clarify boundary issues and relations of the diagnoses with regard to each other.

This study presents some insights into the capacity of scaling similarities of patient profiles. However, it cannot cover the entire field to be researched. For this reasons, we see three limitations: (1) The diagnostic structures in this study have been determined based on cross-sectional assessments of psychopathology, time criteria, and

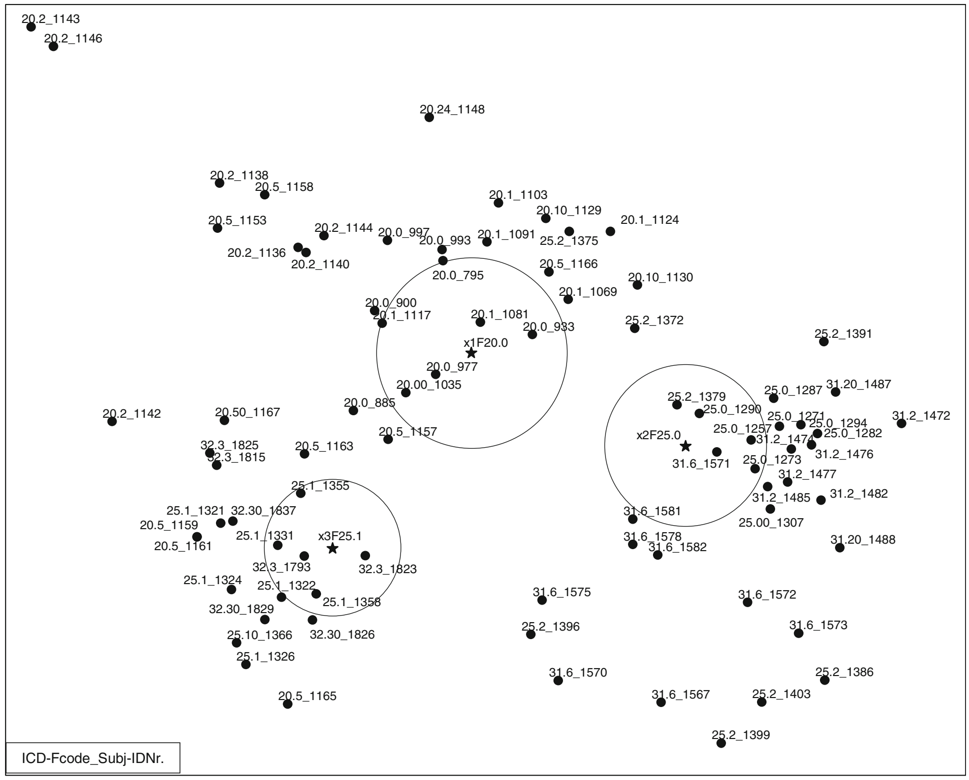

Fig. 3 The same map as in Fig. 1 is presented, including three additional cases (depicted as *stars*) from another sample (x1F20.0, x2F25.0, and x3F25.1). The plotted *circles* comprise the nearest five neighbors

information about course and outcome are not included. (2) The AMDP scale of psychopathology is targeted primarily for the diagnostic area of psychosis. To achieve an equally well-structured map in other areas such as anxiety or personality disorders, the current methodological approach would have to be extended to other diagnostic assessments. (3) Although the robustness of the parallel modeling of all symptoms compensates for some inaccuracy, the diagnostic structures are strongly depending on the quality of the clinical assessments.

Besides these shortcomings that can hopefully be wiped out in future studies, the approach allows for practical procedures supporting the clinical work: Fig. 3, which is not presented in the results section, is an example of a proposal for an automated diagnostic tool, based on the AMDP symptom profiles. In Fig. 3, once again the same map is presented as in Figs. 1 and 2, but this time three additional prototypical patients from a different sample are included (depicted as stars and labeled with an "x" in front of the diagnostic labels). The concentric circles around the stars comprise the area that includes the nearest five neighbors. This sample of patients also stems from the Psychiatric Hospital of the Ludwig-Maximilians University in Munich, but comprises those who were admitted and discharged between March 2005 and July 2007 ($N = 2{,}656$). The selected patients are also prototypical cases (determined by the ranking of the summed inter-correlations of the symptom profiles) diagnosed with paranoid schizophrenia (F20.0), schizoaffective disorder, manic type (F25.0), or schizoaffective disorder, depressive type (F25.1). It is evident that for each of the chosen examples, three out of the nearest five neighbors belong to the corresponding diagnostic group. This is a convincing result, considering that the base ratio under random conditions for this to happen is only 0.006. At this point, it also has to be kept in mind that the map was calculated solely based on the AMDP symptom profiles and that the diagnostic labels were only added later. Hence, the presented procedure can be seen as a proposal for an automated diagnostic tool. Based on the fundamentals presented in this paper, each patient could be assigned with a diagnosis derived solely from his or her AMDP symptom profile at admission. A prototypical map could be automatically generated from the symptom profiles, and the corresponding diagnosis of a given patient could be determined by the diagnoses of his or her nearest neighbors in the map. One of the advantages of such an approach, for instance compared to a logical decision tree approach, is its robustness. While in the sequential procedure of a decision tree, one incorrect piece of information (e.g. an incorrect rating of a symptom by a clinician) can already lead early on in the decision algorithm to the choice of an incorrect bifurcation and therefore a wrong diagnosis, in the approach based on diagnostic maps presented here, all criteria are considered in a parallel manner. Furthermore, a logical decision tree approach is based on the assumption that there is one and only one correct diagnosis applicable, which is incompatible with the current knowledge regarding psychiatric diagnoses. This problem is better solved in Bayes, e.g. [17] or grade-of-membership approaches, e.g. [8], since these models allow a case to be assigned to multiple diagnoses. However, disadvantages of the former method can be seen in the prerequisite of a large sample to enable a proper estimation of the probabilities and the dependence of these estimates on the sample [15], while the disadvantages of the latter method can be seen in the fact that to enable an assessment of the associations with certain prototypes, they have to be predefined (even if they are empirically derived). Again, the approach based on diagnostic maps is not subject to such constraints. The position of a particular case can be determined with regard to the relations to all other cases of a population, and no restricting a priori assumptions about prototypes or estimates about probabilities have to be made. As demonstrated in the above-mentioned example, such a robust placement of a case also allows for multiple diagnoses to be associated with the case.

One of the challenges of psychiatric diagnosis and classification, also in view of the upcoming revisions of the major classification systems, is the debate about the categorical and dimensional aspects of the disorders. However, in the past few years, the question has shifted from whether or not to consider one approach in favor of the other to how to best implement dimensional approaches in the predominantly categorical classification systems. Today, it seems to be clear that both perspectives have essential advantages that need to be considered. In this study, we present an approach that allows the strengths of both the categorical and the dimensional point of view to be exploited at the same time. A multidimensional diagnostic map including the positions of cases, calculated based on their symptom profiles, allows for a structurally neutral and diagnostically independent approach. As no assumptions are required about clusters or dimensions, in the continuous space not only the relations of and transitions between diagnostic groups but also the position of individual cases in and between clusters can be examined with regard to their psychopathological picture and diagnostic association. Of course, the approach presented here is restricted to a cross-sectional AMDP assessment of psychopathology, but it could in principle be expanded to other clinical measures.

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